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Moriya et al.

[11] **4,378,000**

[45] **Mar. 29, 1983**

[54] **FUEL SUPPLY DEVICE FOR INTERNAL COMBUSTION ENGINE**

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[73] Assignee: **Hitachi, Ltd.,** Tokyo, Japan

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[22] Filed: **Mar. 18, 1981**

[30] **Foreign Application Priority Data**

Mar. 19, 1980 [JP] Japan 55-35559

[51] **Int. Cl.**[3] **F02M 39/00**

[52] **U.S. Cl.** .... **123/442;** 123/445; 261/44 F; 261/64 B

[58] **Field of Search** .... 123/442, 445, 301, 302, 123/585, 586; 261/44 F, 50 A, 64 B, 82

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Primary Examiner—Charles J. Myhre
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Attorney, Agent, or Firm—Antonelli, Terry & Wands

[57] **ABSTRACT**

A fuel supply device for an internal combustion engine having an intake manifold includes a throttle body defining therein an intake passage communicating at one end thereof with the intake manifold. A flow accelerating valve arranged in the intake passage upstream of a throttle valve cooperates with the wall surface of the intake passage to define a flow accelerating passage of a smaller flow area than the intake passage. The flow accelerating valve is angularly movable in response to a change in the intake fluid flow between a fully closed position in which the flow accelerating passage has a minimum flow area and a fully open position in which the flow accelerating passage has a maximum flow area, to thereby control the flow area of the flow accelerating passage. A fuel injector injects liquid fuel into the accelerated intake fluid flow passing through the flow accelerating passage.

12 Claims, 7 Drawing Figures

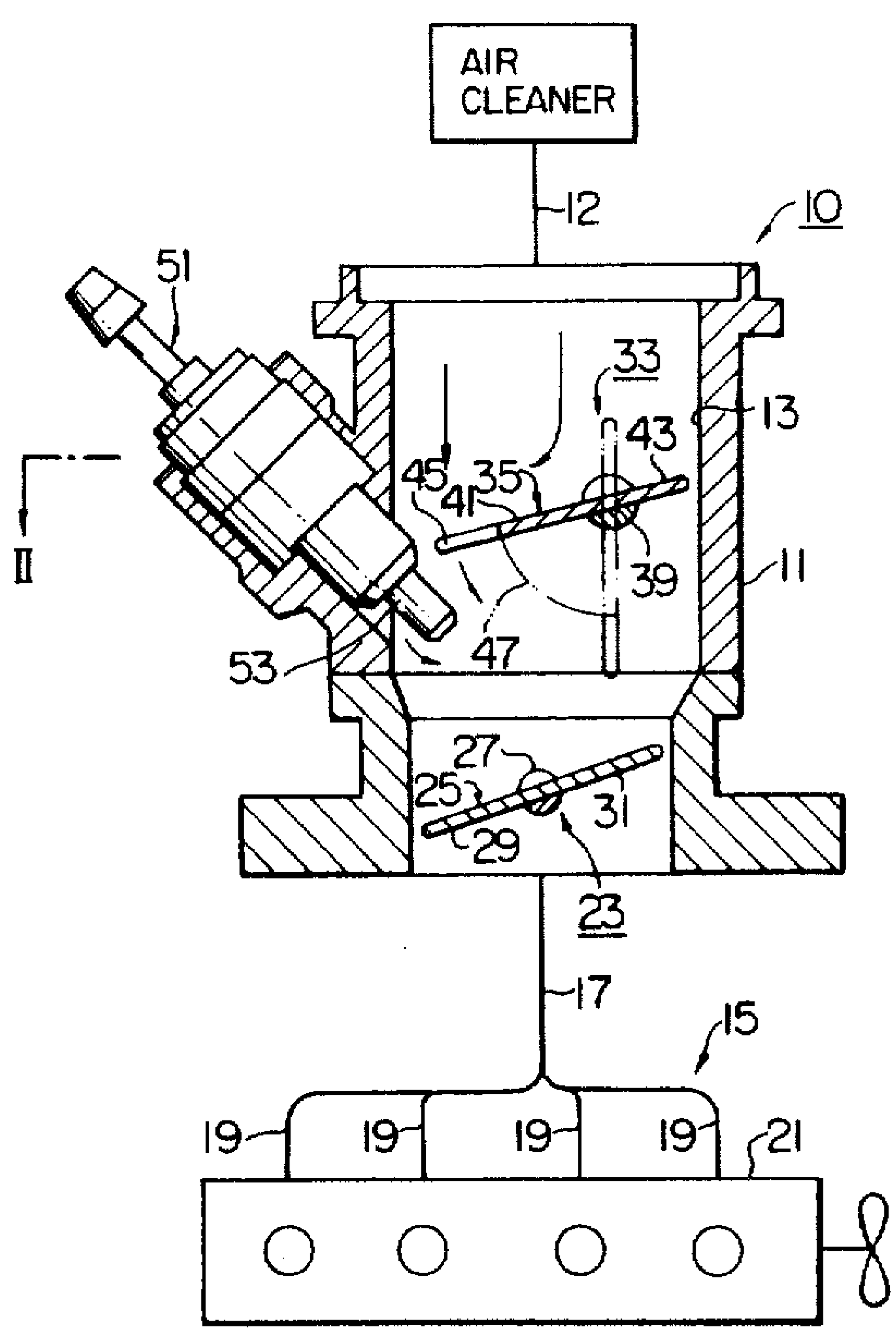
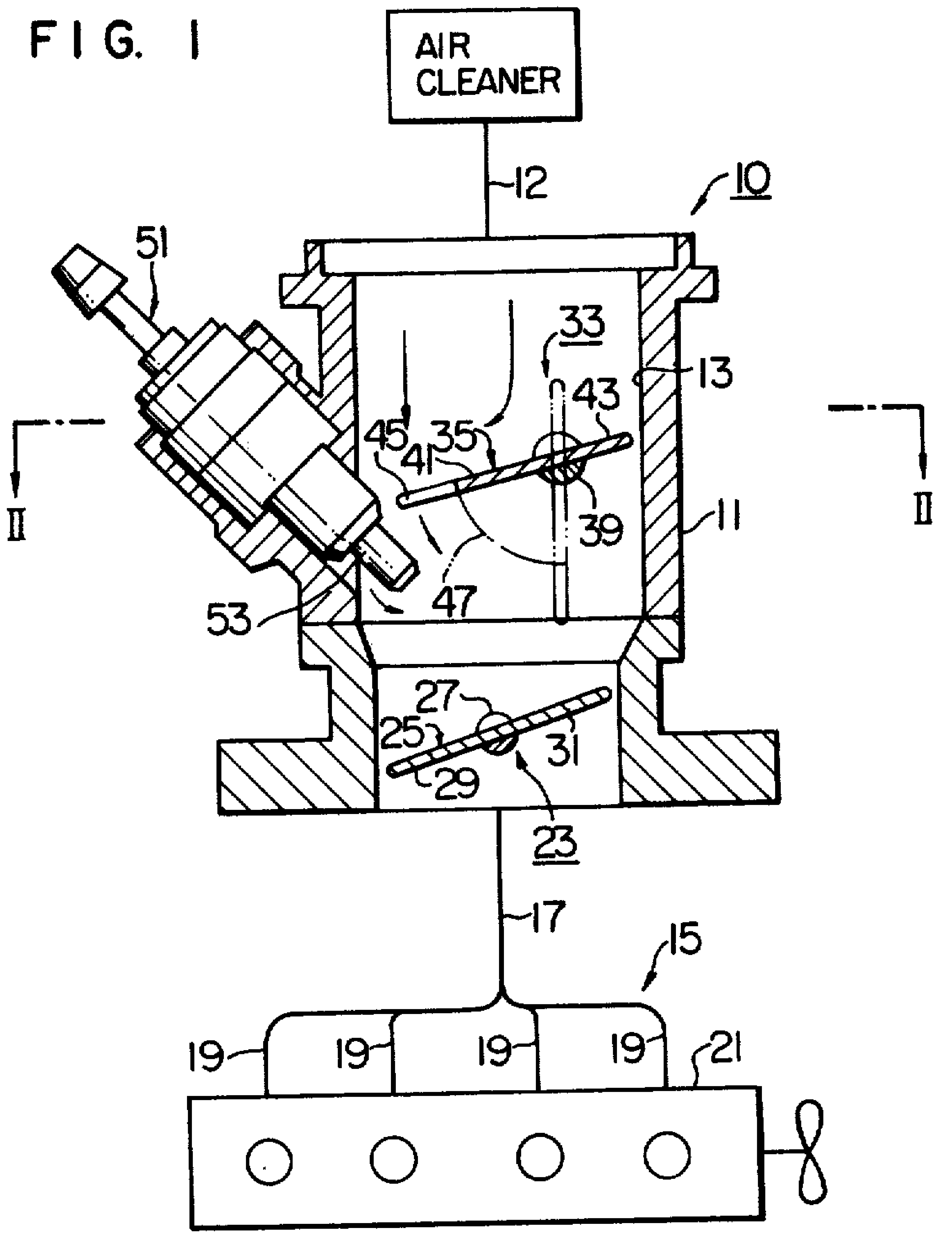
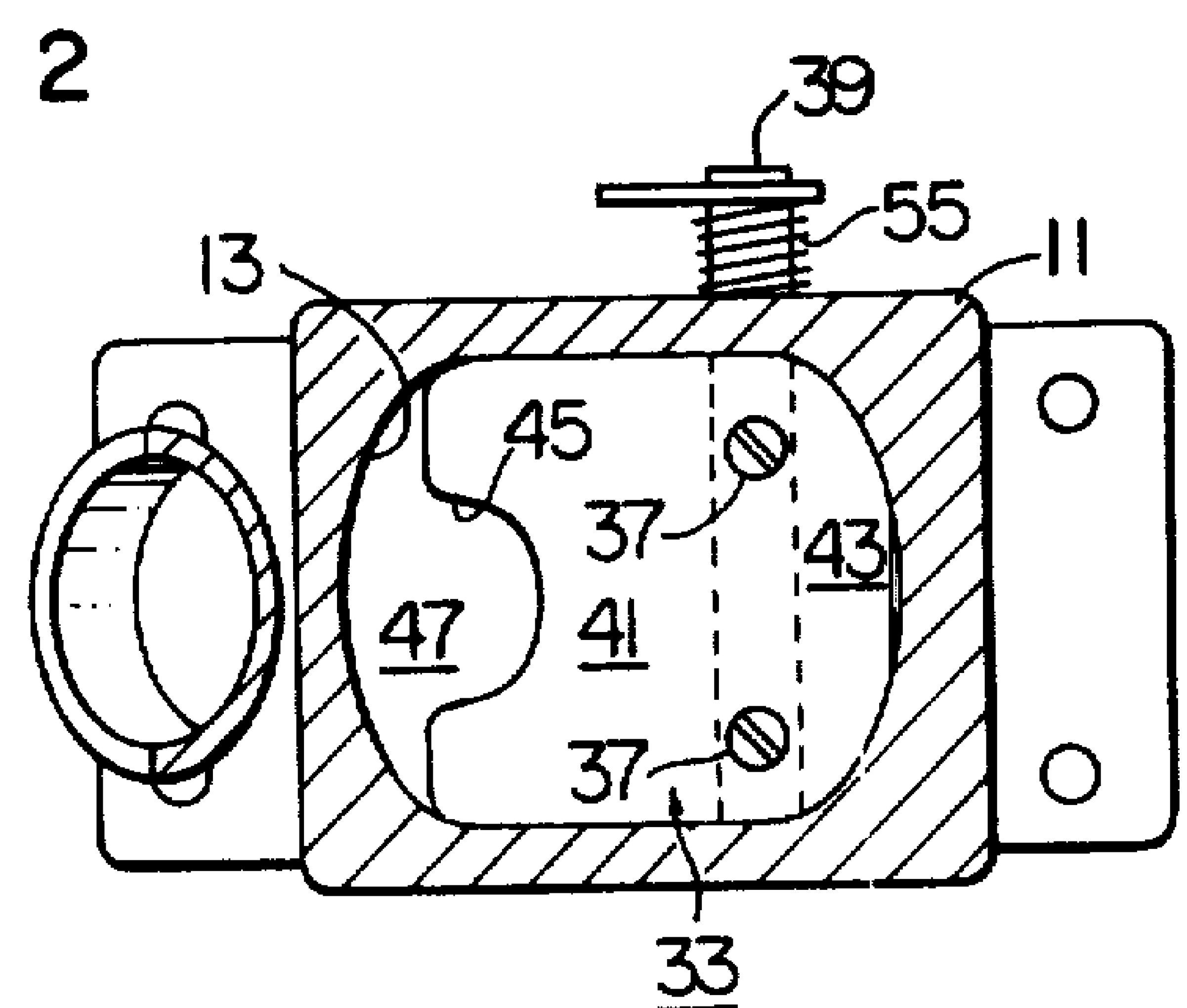


FIG. 1



AIR CLEANER
12
10
51
33
13
43
45
41
35
II
II
39
11
47
53
27
25
31
29
23
17
15
19
19
19
19
21

FIG. 2



39
55
11
13
45
37
43
47
41
37
33

FIG. 3

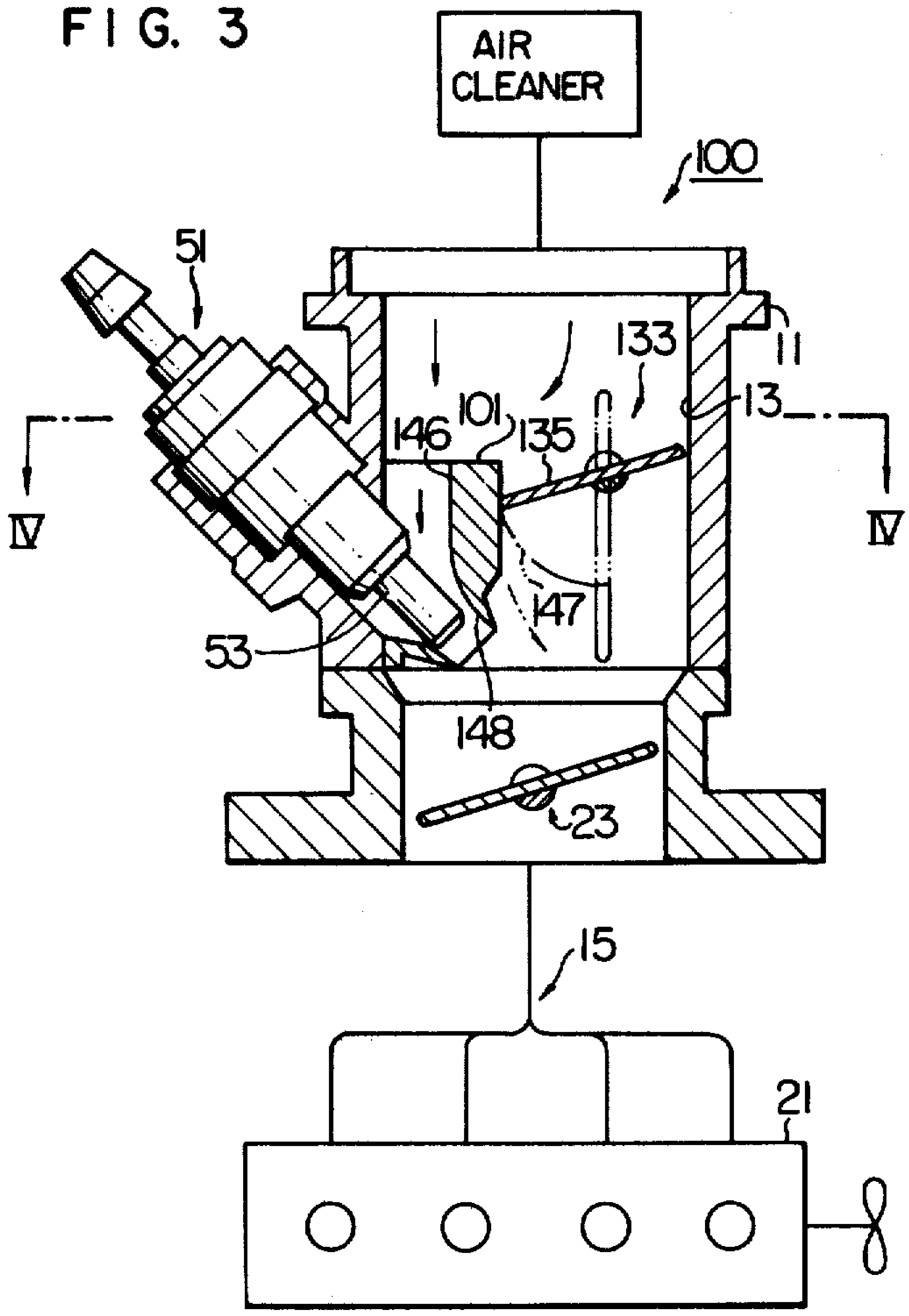

AIR
CLEANER
100
51
133
11
13
101
146
135
IV
IV
147
53
148
23
15
21

FIG. 4

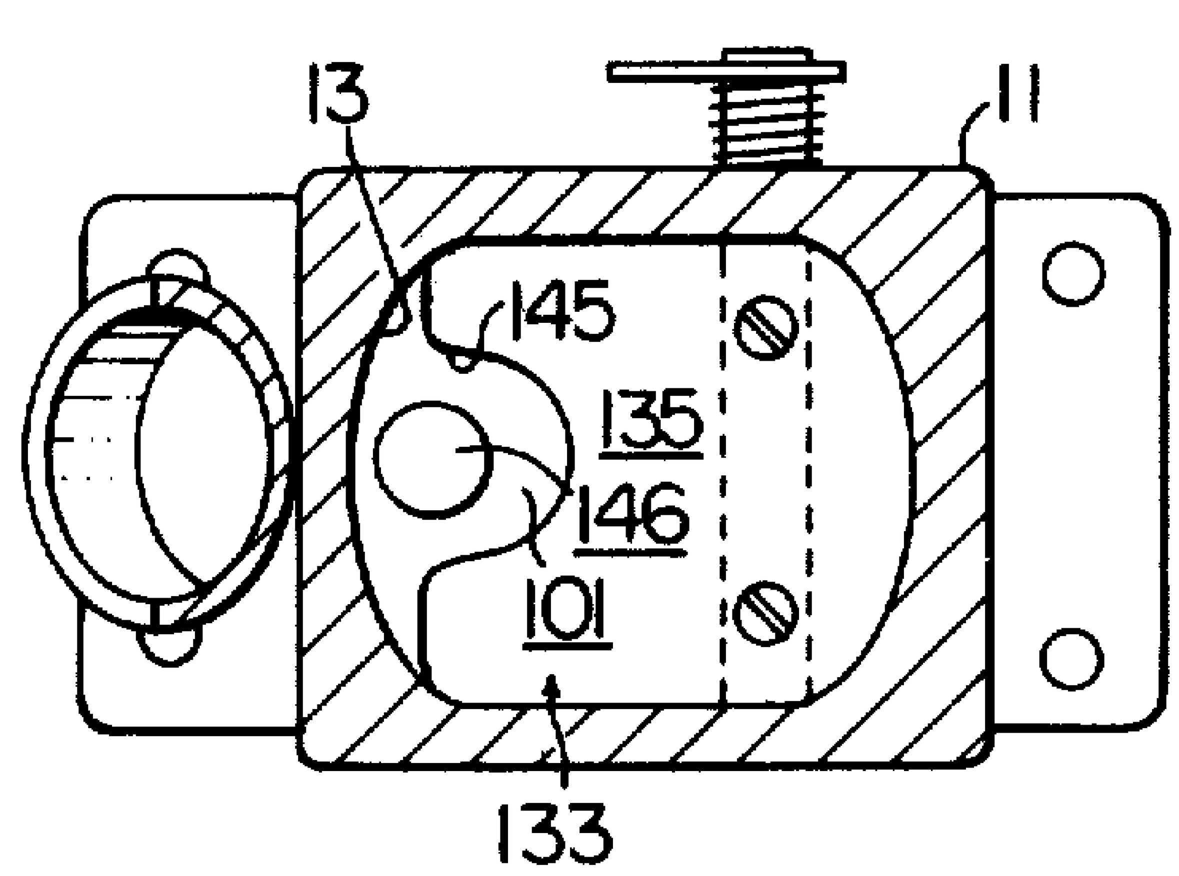

13
11
145
135
146
101
133

FIG. 5

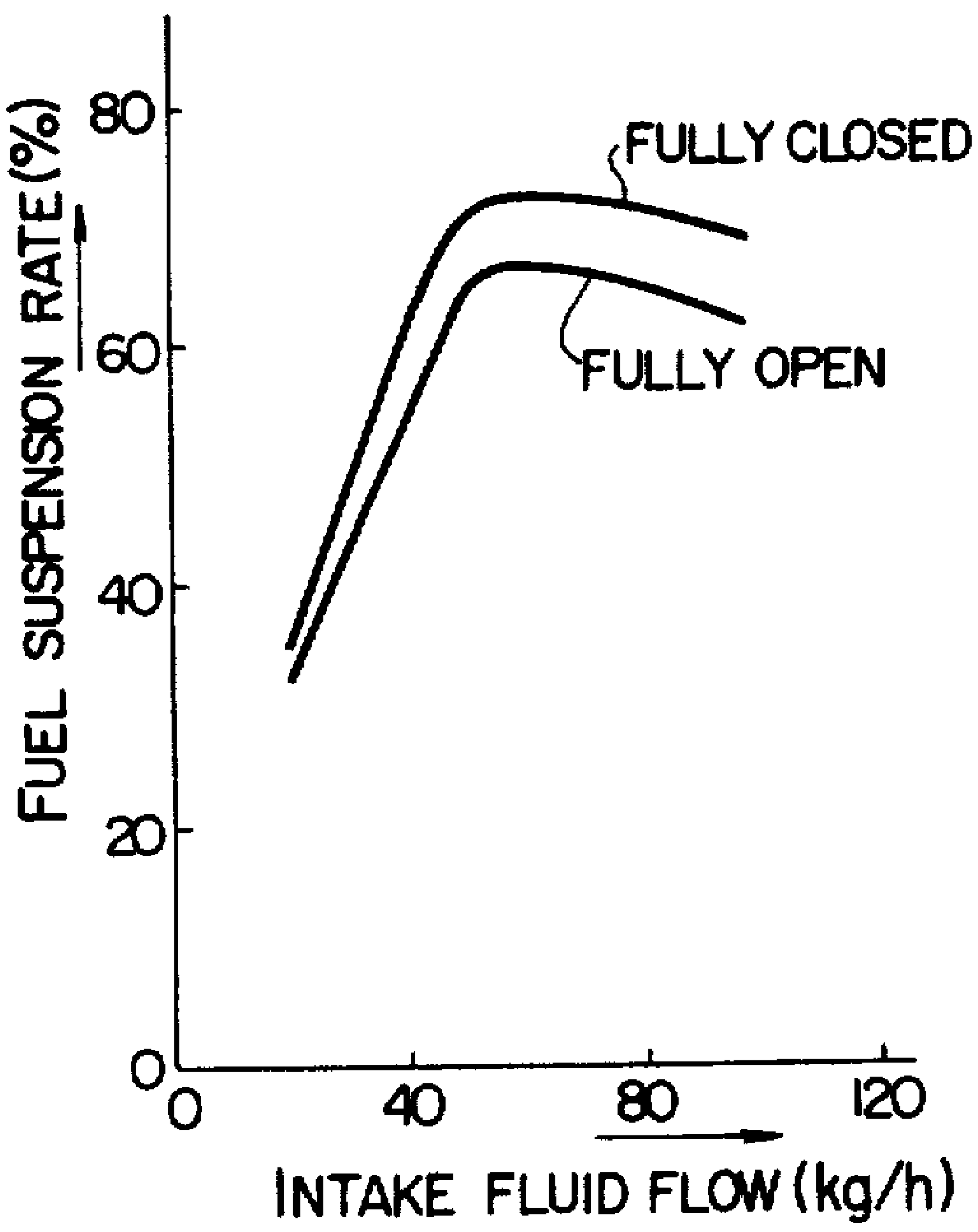


FIG. 7

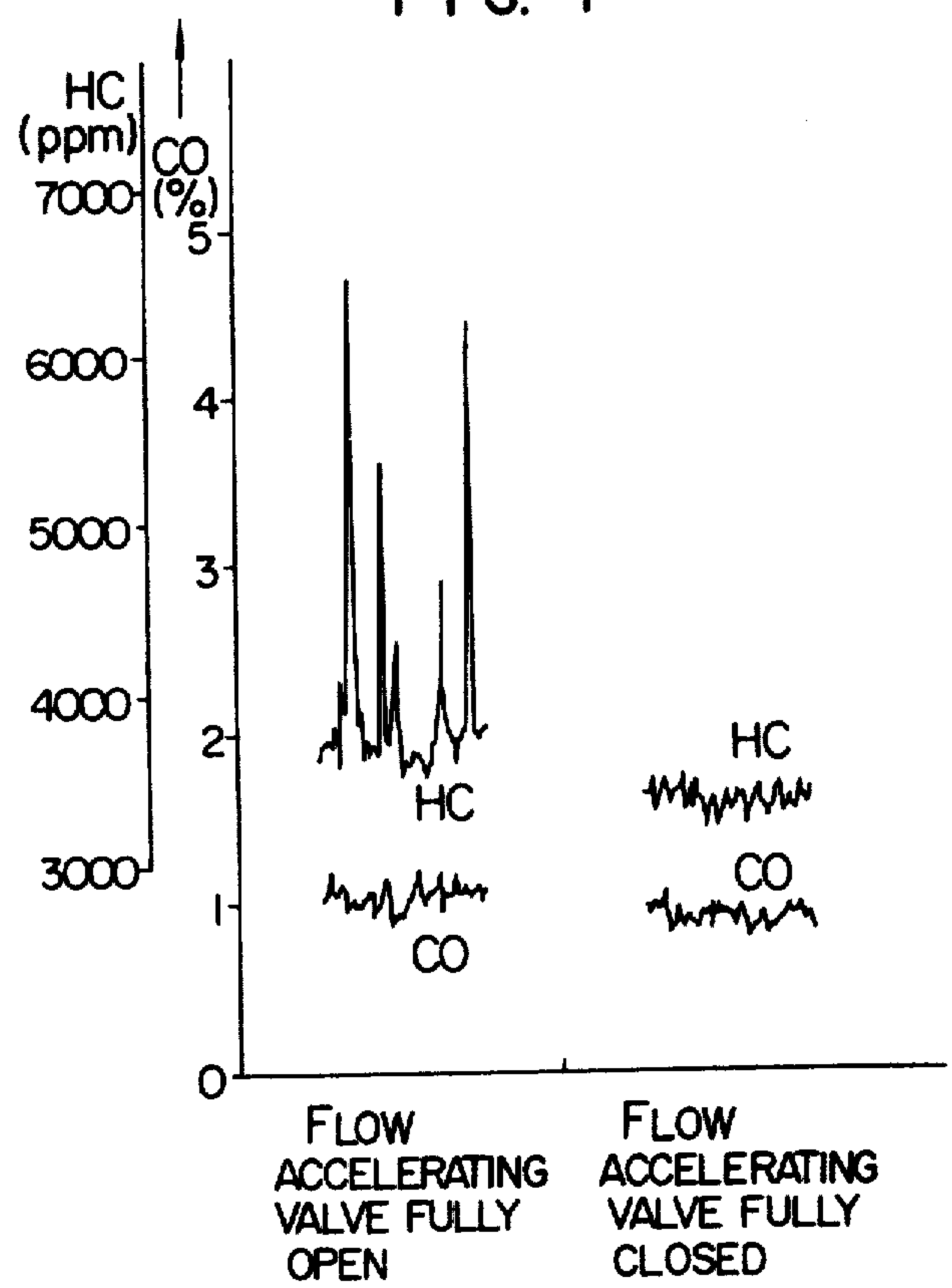
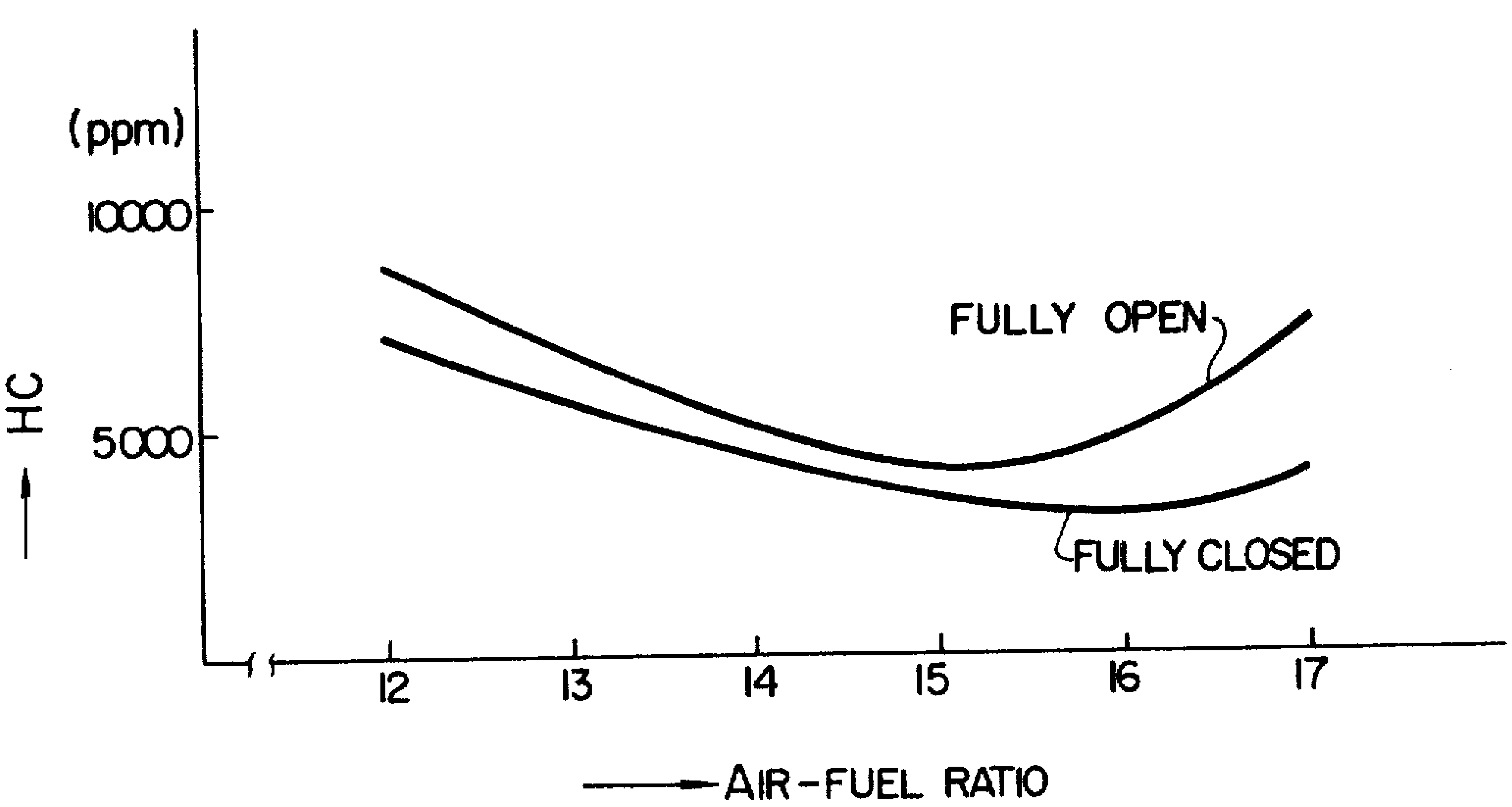


FIG. 6



FUEL SUPPLY DEVICE FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a fuel supply device for an internal combustion engine, including a fuel injector for injecting pressurized liquid fuel.

2. Description of the Prior Art

A so-called multi-point fuel injection system for an internal combustion engine is known which comprises a plurality of fuel injectors each mounted in one of a plurality of branch pipes of an intake manifold respectively communicating with a plurality of cylinders of the engine. Due to the fact that this multi-point fuel injection system has a plurality of fuel injectors and means for controlling fuel injections effected by the plurality of fuel injectors is complex in construction, the problem has arisen that a fuel supply system including the fuel injection system is high in cost. To obviate this problem, proposals have been made to use what is generally referred to as a single-point fuel injection system which comprises a single fuel injector arranged upstream or downstream of a throttle valve mounted in an intake passage defined in a throttle body. However, the single-point fuel injection system having its fuel injector disposed downstream of the throttle valve suffers the disadvantage that because the fuel injector is directly influenced by variations in the negative or subatmospheric pressure in the intake manifold, means for effecting control of fuel injections by the single fuel injector becomes complex in construction, thereby causing an increase in cost of the fuel supply system.

A throttle body fuel injection system having a fuel injector arranged upstream of a throttle valve as disclosed in U.S. Pat. No. 4,130,095, for example, has another problem that, since the intake fluid flow through the intake passage upstream of the throttle valve at an idling operation of engine and at a high-load and low rotational speed of engine has a low speed, the liquid fuel injected from the fuel injector is not sufficiently atomized to change the liquid fuel into a mist of uniformly broken-down minuscule particles of fuel and uniform fuel-air mixtures are unobtainable.

It would be possible to reduce cost in producing the fuel supply system, if the pressure at which the liquid fuel is injected from the fuel injector is lowered. However, it would be impossible to obtain uniform fuel-air mixtures if the pressure at which the liquid fuel is injected is lowered, because this would make it impossible to obtain sufficient atomization of the liquid fuel to change the liquid fuel into a mist of uniformly broken-down minuscule particles of fuel.

SUMMARY OF THE INVENTION

An object of this invention is to provide a fuel supply device for an internal combustion engine capable of reducing the cost of a fuel supply system as a while.

Another object is to provide a fuel supply device which enables enough atomization of the liquid fuel to be obtained in spite of the fact that the pressure at which the liquid fuel is injected is lowered.

Yet another object is to provide a fuel supply device capable of feeding uniform fuel-air mixtures to the engine to permit combustion in engine combustion chambers to take place effectively in good condition.

A further object is to provide a fuel supply device capable of feeding uniform fuel-air mixtures to the engine to thereby reduce harmful constituents in exhaust emissions.

A still further object is to provide a fuel supply device lending itself to ready assembling in a fuel supply system of the prior art without essentially modifying the same.

According to the invention, there is provided a fuel supply device for an internal combustion engine including an intake manifold, comprising a throttle body defining therein an intake passage having one end thereof communicating with the intake manifold, and a throttle valve in the intake manifold for controlling intake fluid flow introduced into the engine through the intake passage and the intake manifold. A accelerating means is disposed in the intake passage upstream of the throttle valve, with the flow accelerating means cooperating with the wall surface of the intake passage to define therein an accelerating flow passage having its flow area less than that of the intake passage. The intake fluid flow passing through the intake passage is accelerated when the intake fluid flow passes through the accelerating flow passage. The flow accelerating means is movable in response to a change in the intake fluid flow introduced into the engine through the intake passage between a fully closed position in which the accelerating passage has a minimum flow area and a fully open position in which the accelerating flow passage has a maximum flow area, to control the flow area of the accelerating flow passage. A fuel injector includes a nozzle disposed upstream of the throttle valve and downstream of the flow accelerating means when it is in its fully closed position with the fuel injector injecting liquid fuel through the nozzle into the accelerated intake fluid flow passing through the accelerating flow passage.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a longitudinal sectional view of the fuel supply device in accordance with one embodiment of the invention;

FIG. **2** is a sectional view taken along the line II—II in FIG. **1**, showing the fuel supply device with the fuel injector being removed;

FIG. **3** is a longitudinal sectional view of the fuel supply device in accordance with another embodiment of the invention;

FIG. **4** is a sectional view taken along the line IV—IV in FIG. **3**, showing the fuel supply device with the fuel injector being removed;

FIG. **5** is a graph showing the results of experiments conducted on the fuel supply device shown in FIG. **3**, showing the relation between the intake fluid flow and the rate of fuel suspension of the liquid fuel in the air with the opening of the flow accelerating valve being used as a parameter;

FIG. **6** is a graph showing the results of experiments carried out on the fuel supply device shown in FIG. **3**, showing the relation between the air-fuel ratio and the mean value of concentration of the hydrocarbons in exhaust emissions with the opening of the flow accelerating valve being used as a parameter; and

FIG. **7** is a graph showing the results of experiments conducted on the fuel supply device shown in FIG. **3**, showing the relation between time and actually measured values of concentrations of the HC and CO in exhaust emissions with the flow accelerating valve being fully closed and fully open.

DETAILED DESCRIPTION OF THE PREFFERED EMBODIMENTS

Referring to FIGS. 1 and 2, the fuel supply device according to the invention generally designated by the numeral **10** comprises a throttle body **11** defining therein an intake passage **13** communicating at one end thereof with a conventional conduit **12** connected to an air cleaner and at the other end thereof with a conventional intake manifold generally designated by the reference numeral **15** which is schematically shown. The intake manifold **15** includes a collector pipe **17** and branch pipes **19** respectively connected to cylinders of an engine **21** schematically shown. The throttle body **11** can be connected to the conventional conduit **12** connected to the air cleaner and to the collector pipe **17** of the conventional manifold **15** without in any way modifying the constructions of these conventional structures.

A throttle valve generally designated by the reference numeral **23** is arranged in the intake passage **13** and is angularly movable in interlocking relationship to an accelerator pedal of a vehicle, not shown, to control intake fluid flow through the intake passage **13** and the intake manifold **15** into the engine **21**. The throttle valve **23** includes a planar plate generally designated by the reference numeral **25** of a shape substantially complementary to the cross-sectional configuration of the intake passage **13**, and a shaft **27** secured to the planar plate **25** and rotatably supported by the throttle body **11**. The shaft **27** has an axis thereof extending perpendicular to the longitudinal axis of the intake passage **13** and the planar plate **25** into two halves **29** and **31** of substantially the same surface area.

A flow accelerating valve generally designated by the reference numeral **33** is arranged in the intake passage **13** upstream of the throttle valve **23**. The flow accelerating valve **33** includes a planar plate generally designated by the reference numeral **35**, and a shaft **39** fastened to the planar plate **35** by screws **37** (FIG. **2**) and rotatably supported by the throttle body **11**. The shaft **39** has an axis thereof extending perpendicular to the longitudinal axis of the intake passage **13** and divides the planar plate **35** into two plate sections **41** and **43**, one plate section **41** having a larger surface area than the other plate section **43**. The one plate section **41** is formed with an indentation **45** which cooperates with the wall surface of the intake passage **13** to define therein an accelerating flow passage **47** smaller in flow area than that of the intake passage **13**. Due to the difference in area between the one plate section **41** and the other plate section **43**, the planar plate **35** is angularly movable in response to a change in the intake fluid flow through the intake manifold **15** into the engine **21** between a fully closed position shown in solid lines in FIG. **1**, in which the accelerating flow passage **47** has a minimum flow area and a fully open position shown in dash-and-dot lines in FIG. **1**, in which the accelerating flow passage **47** has a maximum flow area, to control the flow area of the accelerating passage **47**.

A fuel injector generally designated by the reference numeral **51**, capable of injecting liquid fuel at a constant injection pressure in the range between 0.7 and 1.0 kg/cm^2, includes a nozzle **53**, a valve, not shown, cooperating with the nozzle **53**, and an electromagnetic actuator, not shown, for operating the valve. The nozzle **53** has a tip disposed upstream of the throttle valve **23** and downstream of the flow accelerating valve **33** when the latter is in its fully closed position. The nozzle **53** is directed against the throttle valve **23**, preferably against the half portion **31** of the planar plate **25** of the throttle valve **23** remote from the nozzle **53**, to eject the liquid fuel therethrough against the surface of the half portion **31** of the planar plate **25**.

As clearly shown in FIG. **2**, a coil spring **55** is mounted in concentric relation at one end portion of the shaft **39** of the flow accelerating valve **33** which projects out of the throttle body **11**, to normally urge the flow accelerating valve **33** to move to its fully closed position.

At engine idling operation with the throttle valve **23** disposed near its fully closed position, the flow accelerating valve **33** is disposed in its fully closed position shown in solid lines in FIG. 1. Air introduced through the air cleaner into one end of the intake passage **13** passes to the accelerating flow passage **47** of smaller flow area where the air flow is accelerated. The accelerated fluid flow passes around the nozzle **53** and through the throttle valve **23** into the intake manifold **15** from which it is led to the engine **21**. Meanwhile liquid fuel is injected through the nozzle **53** into the accelerated fluid flow passing through the accelerating flow passage **47**. In spite of the liquid fuel injecting pressure being relatively low or in the range between 0.7 and 1.0 kg/cm^2, it is possible to obtain uniform fuel-air mixtures in the intake passage **13** because the liquid fuel is injected into the accelerated fluid flow and atomized into uniformly broken-down minuscule particles of fuel suitable for producing the uniform fuel-air mixtures. The liquid fuel, which is in the form of droplets of a relatively large size when released from the nozzle **53**, is blown against the surface of the half portion **31** of the throttle valve **23** and flows therealong. The liquid fuel flowing along the surface of the half portion **31** is atomized when it reaches the edge of the planar plate **25** by the stream of a fuel-air mixture flowing through the gap between the outer periphery of the planar plate **25** and the wall surface of the intake passage **13**, to ensure that the fuel-air mixtures introduced into the engine **21** through the intake manifold **15** are uniform.

With an increase in the opening of the throttle valve **23** and an increase in the rotational speed of the engine **21**, the intake fluid flow through the intake passage **13** increases. Upon the intake fluid flow reaching a predetermined value, the flow accelerating valve **33** is angularly moved, against the biasing force of the coil spring **55**, from its fully closed position shown in solid lines in FIG. **1** toward its fully open position shown in dash-and-dot lines in the figure. Stated differently, an increase in the intake fluid flow causes the flow accelerating valve **33** to angularly move toward its fully open position to thereby increase the flow area of the flow accelerating passage **47**. The greater the increase in the flow area of the flow accelerating passage **47**, the smaller becomes the flow accelerating effect achieved by the flow accelerating passage **47**. However, the fluid flow causing the flow accelerating valve **33** to move toward its fully open position against the biasing force of the coil spring **55** has a sufficiently high speed to properly atomize the liquid fuel injected through the nozzle **53** into the intake fluid flow in the intake passage.

At high-load, low rotational speed of the engine **21**, the intake fluid flow through the intake passage **13** is small and the flow accelerating valve **33** moves near to its fully closed position. The fluid flow through the accelerating flow passage **47** is sufficiently accelerated to properly atomize the liquid fuel injected through the nozzle **53**.

Referring to FIGS. **3** and **4**, there is shown a fuel supply device in accordance with another embodiment of the invention generally designated by the numeral **100**. In FIGS. 3 and 4, like reference characters designate parts similar to those shown in FIGS. **1** and **2** and their detailed description will be omitted.

The fuel supply device **100** shown in FIGS. **3** and **4** is different from the fuel supply device **10** shown in FIGS. **1** and **2** in that a partition wall member **101** is mounted on the wall surface of the intake passage **13** defined in the throttle body **11** and divides the accelerating flow passage defined by the flow accelerating valve generally designated by the reference numeral **133** into a first flow passage section **146** and a second flow passage section **147**. More specifically, the partition wall member **101** has an inner surface cooperating with the wall surface of the intake passage **13** to define the first flow passage section **146** of a fixed flow area, and an outer surface cooperating with an indentation **145** formed in the periphery of the planar plate **135** to define the second flow passage section **147** of a variable flow area.

The first flow passage section **146** includes a downstream end portion **148** having a substantially cylindrical wall surface, and the nozzle **53** of the fuel injector **51** is disposed in substantially concentric relation to a part of the downstream end portion **148** of the first flow passage section **146** in such a manner that an annular clearance is formed between the outer periphery of the nozzle **53** and the cylindrical wall surface of the downstream end portion **148**.

The flow accelerating valve **133** is angularly movable in response to the intake fluid flow introduced into the engine **21** to vary the flow area of the second flow passage section **147**, to thereby control the flow area of the accelerating flow passage constituted by the first flow passage section **146** and the second flow passage section **147**. Other parts of the fuel supply device **100** are similar in construction and operation to those of the fuel supply device **10** shown in FIGS. **1** and **2**, so that their description will be omitted.

Experiments were conducted on the fuel supply device **100** shown in FIGS. **3** and **4** in many ways. The results of the experiments are shown in FIGS. **5**–**7**.

The graph shown in FIG. **5** shows the relation between the intake fluid flow which varies depending on the opening of the throttle valve **23** and the rate of fuel suspension of the liquid fuel injected into the intake fluid flow from the nozzle **53** when the flow accelerating valve **133** is forcedly moved to the fully closed position shown in solid lines and the fully open position shown in dash-and-dot lines in FIG. **3**, in road-load condition in which the vehicle runs at constant speed on a flat road. The fluid suspension rate is obtained by the following equation:

$$\text{Fluid suspension rate } (\%) = [(Qf - Qf_1)/Qf] \times 100$$

$$Qf = Qf_1 + Qf_2$$

Where

Qf: volume of liquid fuel injected from nozzle **53**.

Qf_1: volume of liquid fuel deposited on wall surface of intake passage **13** following fuel injection through nozzle **53**.

Qf_2: volume of liquid fuel entrained in intake fluid flow following injection through nozzle **53** and introduced into engine.

FIG. **5** indicates that when the flow accelerating valve **133** is in its fully closed position the fuel suspension rate is higher than when the valve **133** is in its fully open position, i.e., when no flow accelerating valve is essentially provided. This would mean that the liquid fuel injected through the nozzle **53** into the intake fluid flow is satisfactorily atomized by the intake fluid flow accelerated by the flow accelerating valve **133**, so that the liquid fuel is changed into a mist of uniformly broken-down minuscule particles to enable uniform fuel-air mixtures to be obtained. FIG. **5** also indicates that when the throttle valve **23** has its large opening and the intake fluid flow is large and has high speed, atomization of the liquid fuel is markedly promoted.

In FIG. **6**, there is shown a graph showing the relation between the air-fuel ratio of the fuel-air mixtures supplied to the engine **21** and the mean value of concentration of HC (hydrocarbons) in exhaust emissions when the flow accelerating valve **133** is forcibly moved to its fully open position and its fully closed position at engine idling operation. FIG. **6** indicates that when the flow accelerating valve **133** is in its fully closed position, the HC concentration is lower than when the valve **133** is in its fully open position, i.e., when no flow accelerating valve is essentially provided, irrespective of the value of the air-fuel ratio. This would mean that the intake fluid flow accelerated by the flow accelerating valve **133** in its fully closed position sufficiently atomizes the liquid fuel injected through the nozzle **53** to increase the fuel suspension rate, to thereby form uniform fuel-air mixtures to enable the combustion in the combustion chambers of the engine **21** to take place effectively.

The graph shown in FIG. **7** shows the relation between time and the HC and CO (carbon monoxide) concentrations in exhaust emissions (actually measured values) when the flow accelerating valve **133** is forcibly moved to its fully open position and its fully closed position at engine idling operation. FIG. **7** indicates that HC and CO concentrations are lower when the flow accelerating valve **133** is in its fully closed position than when it is in fully open position, i.e., when no flow accelerating valve is essentially provided. FIG. **7** also indicates that the HC and CO concentrations show smaller variations when the flow accelerating valve **133** is fully closed than when it is fully open. A sudden variation in HC concentration occurring when the flow accelerating valve **133** is in its fully open position indicates that no uniform fuel-air mixtures are supplied to the combustion chambers of the engine **21**.

What we claim is:

1. A fuel supply device for an internal combustion engine including an intake manifold, the fuel supply device comprising:

a throttle body defining therein an intake passage having one end thereof communicating with said intake manifold;

a throttle valve in said intake passage for controlling intake fluid flow introduced into the engine through said intake passage and said intake manifold;

flow accelerating means disposed in said intake passage upstream of said throttle valve, said flow accelerating means cooperating with the wall surface of said intake passage to define therein an accelerating flow passage having a flow area less than that of said intake passage, the intake fluid flow passing through said intake passage being accelerated when the intake fluid flow passes through said accelerating flow passage, said flow accelerating means being movable in response to a change in the intake fluid flow introduced into the engine through said intake passage between a fully closed position in which said accelerating flow passage has a minimum flow area and a fully open position in which said accelerating flow passage has a maximum flow area, to control the flow area of said accelerating flow passage; and

a fuel injector having a nozzle disposed upstream of said throttle valve and downstream of said flow accelerating means when the flow accelerating means is in the fully closed position, said fuel injector being adapted to inject liquid fuel through said nozzle into the accelerated intake fluid flow passing through said accelerating flow passage and being disposed so as to be directed toward said accelerating flow passage such that the fuel injected from said injector does not substantially impinge against said flow accelerating means over the entire operating range of the engine.

2. A fuel supply device defined in claim 1, further comprising a wall member disposed in said accelerating flow passage to divide the same into a first flow passage section having a fixed flow area and a second flow passage section having a variable flow area.

3. A fuel supply device for an internal combustion engine including an intake manifold, the fuel supply device comprising:

a throttle body defining therein an intake passage having one end thereof communicating with said intake manifold;

a throttle valve in said intake passage for controlling intake fluid flow introduced into the engine through said intake passage and said intake manifold;

flow accelerating means disposed in said intake passage upstream of said throttle valve, said flow accelerating means cooperating with the wall surface of said intake passage to define therein an accelerating flow passage having a flow area less than that of said intake passage, the intake fluid flow passing through said intake passage being accelerated when the intake fluid flow passes through said accelerating flow passage, said flow accelerating means being movable in response to a change in the intake fluid flow introduced into the engine through said intake passage between a fully closed position in which said accelerating flow passage has a minimum flow area and a fully opened position in which said accelerating flow passage has a maximum flow area, to control the flow area of said accelerating flow passage;

the fuel injector having a nozzle disposed upstream of said throttle valve and downstream of said flow accelerating means when the flow accelerating means is in the fully closed position, said fuel injector injecting liquid fuel through said nozzle into the accelerated intake fluid flow passing through said accelerating flow passage; and

a wall member disposed in said accelerating flow passage to divide the same into a first flow passage section having a fixed flow area and a second flow passage section having a variable flow area, said first flow passage section has a generally cylindrical downstream end portion, said nozzle of said fuel injector is disposed in said downstream end portion with an annular space left between said nozzle and a wall surface of said downstream end portion.

4. A fuel supply device defined in claim 3, wherein said nozzle of said fuel injector is disposed in substantially concentric relation to said downstream end portion of said first flow passage section.

5. A fuel supply device defined in claim 1, wherein said flow accelerating means includes a flat plate having an indentation cooperating with the wall surface of said intake passage to define said accelerating flow passage, and a shaft secured to said flat plate and rotatably supported by said throttle body, said shaft having an axis of rotation extending through said flat plate so as to divide said flat plate into two plate sections, one of said two plate sections having a surface area greater than a surface area of the other plate section, said indentation being provided in said one plate section.

6. A fuel supply device defined in any one of claims 2–4, wherein said flow accelerating means includes a flat plate having an indentation cooperating with the wall surface of said intake passage to define said accelerating flow passage, and a shaft secured to said flat plate and rotatably supported by said throttle body, said shaft having an axis of rotation extending through said flat plate so as to divide said flat plate into two plate sections, one of said two plate sections having a surface area greater than a surface area of the other plate section, said indentation being provided in said one plate section.

7. A fuel supply device defined in claim 6, wherein said indentation in said flat plate cooperates with said wall member to define said second flow passage section of said flow accelerating passage.

8. A fuel supply device defined in any one of claims 1–5, further comprising means for normally biasing said flow accelerating means into the fully closed position, said flow accelerating means being movable against said biasing means in response to an increase in the intake fluid flow introduced into the engine through said intake manifold from said fully closed position toward said fully opened position.

9. A fuel supply device defined in any one of claims 1–5, wherein said nozzle of said fuel injector is directed against said throttle valve.

10. A fuel supply device defined in claim 9, wherein said throttle valve includes a flat plate and a shaft secured thereto and rotatably supported by said throttle body, said shaft of said throttle valve having an axis of rotation extending through said throttle valve so as to divide said flat plate of said throttle valve into two plate sections, said nozzle of said fuel injector being directed to one of said two plate sections of said throttle valve that is remote from said nozzle.

11. A fuel supply device defined in any one of claims 1–5, wherein said fuel injector injects liquid fuel through said nozzle at an injection pressure of approximately 0.7–1.0 Kg/cm^2.

12. A fuel supply device defined in claim 10, wherein said fuel injector injects liquid fuel through said nozzle at an injection pressure of approximately 0.7–1.0 Kg/cm^2.

* * * * *